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ABSTRACT

A study investigated children's use of three acoustic parameters (intensity, fundamental frequency, and duration) in the production of two-syllable nonsense words. Subjects were six children each at ages 2, 3, and 4 years with age-appropriate language skills and normal hearing sensitivity. An examiner produced eight novel two-syllable words of similar phonological structure in relation to objects unfamiliar to the children, and then elicited them by imitation. The words were stressed on one or the other syllable. Acoustic analysis of the words elicited suggests that all three of the acoustic features measured are rather poorly controlled at age 2. At 3, both intensity and fundamental frequency appear to be used consistently to mark the stressed syllable regardless of its position in the word. However, it was not until age 4 that the children seemed to have control over duration as a feature for marking word stress. It is also concluded that the data argue for a neutral start hypothesis for early stress production. (MSE)

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AN ACOUSTIC ANALYSIS OF YOUNG CHILDREN'S PRODUCTIONS OF WORD STRESS

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Prosodic phenomena such as stress have tended to receive little attention in the literature on child phonology. Word stress, also sometimes called accent or stress-accent, is defined as giving prominence to one or more syllables of a multi-syllabic word. In adult English, stressed syllables can be identified by several acoustic characteristics:

1. Intensity (stressed syllables may be louder).
2. Fundamental frequency (stressed syllables may be higher or lower in pitch).
3. Duration (stressed syllables may be louder).
4. Frequency spectrum (vowel quality in stressed syllables may be more distinct).

In adult English, the actual use of these characteristics varies greatly. Any combination of these factors may be used to mark the stressed syllable (or syllables) in a word.

Not much is known about how or when children make use of these acoustic features to mark stress in words. Allen and Hawkins (1980) have suggested that children have particular difficulty in the reduction of unstressed syllables, that is, in decreasing the length or reducing the vowel quality of unstressed syllables. They observed that young children instead tend to either delete unstressed syllables altogether or to produce them with stress.

In a study of five children between two and four years of age, Allen and Hawkins (1980) found that correct reduction of unstressed syllables ranged from only 35 to 65%. They also noted that the tendency to completely delete unstressed syllables occurred most often in word-initial position (e.g., [weI] for away).

In another study, Allen and Hawkins (1980) looked at children's use of fundamental frequency as well as duration. In words produced by three children approximately three years of age, stressed syllables were both longer in duration and higher in pitch.

In both of these studies, real words were the focus of analysis. In later studies (Allen & Hawkins, 1980), nonsense words were constructed to allow for control over stress placement. Words were identical in segmental content, but differed in stress placement (e.g., ['taki] and [ta'ki]). Data from English speaking children from approximately three to seven years of age indicted that the children had little difficulty perceiving the difference between these pairs of words. However, some of the children had difficulty producing the words with second syllable stress (e.g., [ta'ki]). On the basis of these studies, Allen and Hawkins proposed that children are operating with a trochaic constraint, and are biased towards words with falling stress patterns.

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Informal observations of young children's early attempts at two-syllable words have suggested that such words are often produced with two equally stressed syllables or with stress on the wrong syllable (e.g., Leopold, 1947; Menn, 1976). Two descriptive studies of children approximately two years of age have also reported this use of level stress or misplaced stress. Klein (1984) looked at the multisyllabic productions of a single English-speaking two-year-old, and found a great deal of variability. Some words were produced with correct stress, some with misplaced stress, and others with level stress. Interestingly, newer words and imitations of novel words showed the greatest amount of variability. Words that were more established in the child's vocabulary were produced with more consistent stress assignment. Hochberg (1988) looked at the production of stress in four Spanish-speaking children. Spanish has a more even distribution of words with final and penultimate stress than English. At the beginning of the study, when the children were 19 to 22 months of age, accuracy of stress placement was essentially at chance level. The children were no better or worse in accuracy on words with final versus penultimate stress. Over time, three of the children improved in their accuracy of stress production. On the basis of these data, Hochberg argued that children do not show a trochaic bias in their productions, but rather have a "neutral start" and are unbiased towards any particular stress type.

Both Klein's and Hochberg's studies used perceptual transcriptions of stress. The analysis of data based on perceptual transcriptions is of some concern. Interjudge reliability of stress transcription with young children is typically poor. Brammer (1988) found average interjudge reliability for stress transcription increased with subject age, averaging 69% for two-year-olds, 74% for three-year-olds, and 83% for four-year-olds. One possible explanation for the poorer reliability with the younger children is that they may not be consistent in their use of acoustic features for marking stress, and therefore may be providing the listeners with inconsistent or unreliable cues.

The purpose of the present study was to investigate children's use of three acoustic parameters in the production of two-syllable nonsense words. The specific questions addressed were:

1) Which acoustic parameters (intensity, fundamental frequency, duration) are altered?

2) Is there a difference in the use of these acoustic parameters across different age groups?

3) Is there a difference in the use of these parameters when the stressed syllable is in the first position versus the second position of the word?

Method

Subjects were six children each at two, three, and four years of age. All were screened for age-appropriate language skills and normal hearing sensitivity.

Eight novel CVCV words were created, controlling for segmental content and stress placement. All were of the shape CVCV. Two pairs of

syllables, [bə] - [fi] and [bo] - [da], were used. Words were created by altering the placement of these syllables within the word, and altering the placement of stress. The resulting experimental words are shown in Table 1. Referents for each word were unfamiliar objects to the children (e.g., a plastic grip for a bicycle handlebar).

The experiment was conducted in a quiet room while the subject and experimenter played with both familiar toys and the unfamiliar objects. The experimental words were elicited through an imitation procedure. The eight words were presented in a random order, with the restriction that words with identical segmental structure (e.g., ['boda] and [bo'da]) were not presented consecutively. Each object was drawn from a bag by the examiner accompanied with a phrase, such as "Here's a ____." With the younger children, spontaneous imitation of the experimental word often occurred. With the older subjects, imitations often needed to be prompted with the question, "What is it?" or "What's its name?" Repeated presentations of the objects were made in an attempt to elicit at least three token productions of each word. However, it was not always possible to obtain three tokens for all subjects, due to inattention to the task over time. As a result, a different number of productions were obtained for each subject. Table 2 shows the number of productions elicited for each age group for both first syllable stressed and second syllable stressed words. There were slightly fewer second syllable stressed words produced overall, due in part to the tendency of several two-year-old subjects to delete initial unstressed syllables.

All experimental sessions were audiorecorded for later acoustic analysis. Productions that occurred more than 15 seconds after the adult's model were not included in the analyses. Measures of peak fundamental frequency and peak intensity for each syllable were made using a Kay Elemetrics Model 6095 Visipitch. Measures of the absolute duration of each vowel were made from wide band spectrograms (600 Hz analyzing filter) using a Kay Elemetrics Digital Sona Graph Model 7800.

Table 1. Experimental words.

'CVCV	CV'CV
'bəfi	bə'fi
'fibə	fi'bə
'boda	bo'da
'dabo	da'bo

Table 2. Number of words elicited.

Age	'CVCV	CV'CV	Total
2	67	54	121
3	70	65	136
4	74	81	155
Total	211	201	412

Results

The acoustic data were analyzed by three-factor mixed design analyses of variance (ANOVA) with repeated measures on two factors. A separate

analysis was conducted for each of the three acoustic measures. Age (two, three, or four years) served as the between subjects variable. Stress level (stressed or unstressed) and syllable position (first or second) served as within subject variables.

Intensity. Each subject's mean peak intensity for stressed and unstressed syllables in first and second position is shown in Table 3. Results of the ANOVA for intensity revealed that the main effect of stress level was statistically significant, $F(1,15) = 38.96$, $p < .001$, indicating that the stressed syllable was more intense than the unstressed syllable. The main effects of age and syllable position were not significant. However, a two-way interaction between age and stress level was significant, $F(2,15) = 7.86$, $p < .005$. This interaction is displayed graphically in Figure 1. The graph indicates that the stressed syllable was more intense than the unstressed syllable for the three- and four-year-olds, but not for the two-year-olds. No difference was apparent between the three- and four-year-olds.

Fundamental Frequency. Table 4 shows each subject's mean peak fundamental frequency for the stressed and unstressed syllables in first and second position. The results of the ANOVA found the main effect of stress level to be statistically significant, $F(1,15) = 11.28$, $p < .005$, confirming that the peak frequency of the stressed syllable was higher than that of the unstressed syllable. The main effects of age and syllable position were not significant. No interaction effects reached the significance level of .05. However, the two-way interaction between age and stress level approached significance, $F(2,15) = 3.54$, $p = .055$, which suggests that the peak frequency of the stressed syllable was not consistently higher for all age groups. This interaction is shown in Figure 2, and suggests that the effect of stress is present for the three- and four-year-olds, but not for the two-year-olds. No difference was observed between the three- and four-year-olds.

Duration. The mean duration of the vowels in stressed and unstressed syllables in first and second position for each subject is shown in Table 5. The results of the duration ANOVA found the main effect of stress level to be statistically significant, $F(1,15) = 127.02$, $p < .001$, indicating that stressed syllables were longer on the average than unstressed syllables. The main effect of syllable position was also significant, $F(1,15) = 44.35$, $p < .001$. That is, the duration of the second syllable was significantly longer than the duration of the first syllable. The main effect of age was not significant.

As with the other measures, there was a significant interaction between age and stress level, $F(2,15) = 8.53$, $p < .005$. This interaction is displayed in Figure 3, which indicates that the effect of stress level is strongest for the three- and four-year-olds, although it is also present to a degree for the two-year-olds. The interaction between stress level and syllable position was also significant, $F(1,15) = 52.06$, $p < .001$. This interaction is shown in Figure 4, and indicates that the stressed syllable is longer if in the second position. Finally, the three-way interaction between age, stress level, and syllable position was significant, $F(2,15) = 14.75$, $p < .001$. Figure 5

Table 3. Mean intensity values (in dB) for each subject.

Age	Subject	Stressed Syllable		Unstressed Syllable	
		First	Second	First	Second
2	1	52.00	54.70	52.00	52.30
	2	49.30	48.50	53.30	44.60
	3	47.50	48.90	48.90	48.20
	4	48.40	46.50	49.70	50.30
	5	50.00	54.79	52.20	49.90
	6	50.10	54.00	52.20	50.30
	M	49.55	51.23	50.95	49.27
	SD	1.56	3.68	1.78	2.64
3	1	43.54	41.45	40.09	38.77
	2	50.00	49.90	47.60	45.20
	3	53.36	53.85	50.54	47.00
	4	54.75	49.56	47.44	45.50
	5	58.85	57.00	57.25	57.69
	6	54.45	62.75	54.25	48.55
	M	52.49	52.42	49.55	47.12
	SD	5.22	7.27	6.03	6.12
4	1	53.10	52.10	47.40	48.55
	2	54.50	54.93	53.20	51.50
	3	55.60	54.90	50.24	51.50
	4	54.00	55.40	49.63	48.64
	5	46.79	48.85	43.38	46.77
	6	46.92	52.54	40.08	48.54
	M	51.82	53.12	47.32	49.86
	SD	3.93	2.50	4.82	2.86

Table 4. Mean fundamental frequency values (in Hz) for each subject.

Age	Subject	Stressed Syllable		Unstressed Syllable	
		First	Second	First	Second
2	1	464.20	496.70	454.00	476.20
	2	325.80	317.20	367.30	297.50
	3	297.50	314.70	303.50	308.90
	4	289.50	250.00	275.80	300.60
	5	308.40	309.40	277.30	301.70
	6	353.40	316.00	326.70	388.70
	M	339.80	334.00	334.00	345.60
	SD	65.06	83.80	67.96	72.84
3	1	282.90	259.80	270.10	248.30
	2	279.25	293.11	238.11	250.08
	3	279.40	286.73	270.36	247.50
	4	335.50	334.56	263.22	259.38
	5	270.83	277.67	259.08	282.17
	6	359.46	435.25	275.75	269.00
	M	301.22	314.52	279.44	259.41
	SD	36.84	64.12	48.64	13.87
4	1	284.80	293.30	263.80	255.90
	2	269.30	272.30	225.40	258.50
	3	277.90	269.90	240.20	280.00
	4	255.30	273.55	255.80	235.00
	5	301.50	300.00	285.28	280.46
	6	442.10	407.08	291.58	319.08
	M	305.15	302.69	260.34	274.49
	SD	68.84	52.61	25.52	28.85

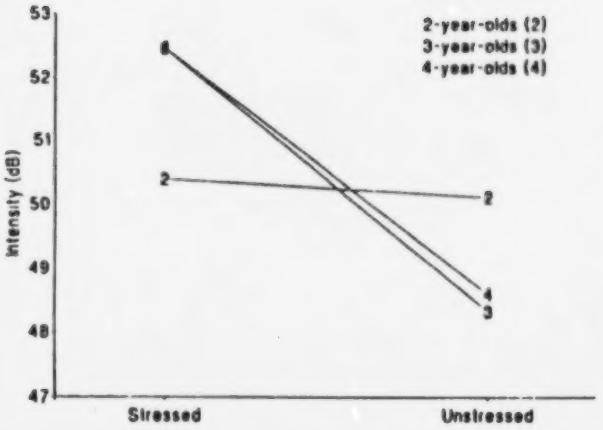

Figure 1. Two-way age by stress level interaction for intensity measure.

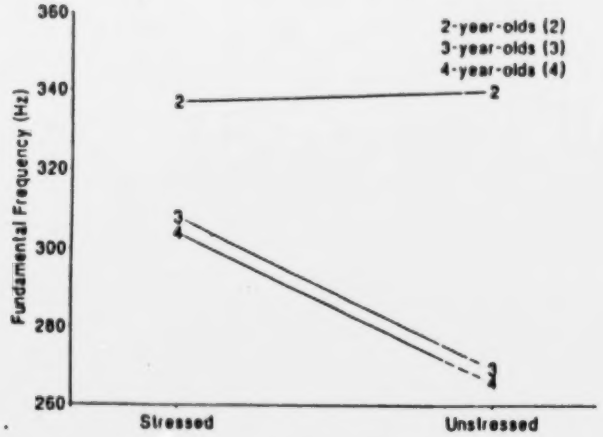

Figure 2. Two-way age by stress level interaction for frequency measure.

Table 5. Mean duration values (in cs) for each subject.

Age	Subject	Stressed Syllable		Unstressed Syllable	
		First	Second	First	Second
2	1	20.40	45.90	15.00	39.90
	2	23.60	37.80	22.50	33.90
	3	16.50	22.70	17.00	18.30
	4	14.20	26.50	17.50	15.70
	5	18.60	34.20	17.30	33.50
	6	19.60	31.70	20.80	17.50
	M	18.82	33.13	18.35	26.47
	SD	3.25	8.26	2.76	10.47
3	1	22.77	33.64	14.73	30.04
	2	22.40	36.10	15.00	17.47
	3	17.81	28.17	10.71	16.55
	4	19.25	34.81	14.25	17.00
	5	20.54	33.77	21.95	27.73
	6	16.32	22.00	8.50	14.73
	M	19.85	31.42	14.19	20.92
	SD	2.55	5.35	4.60	6.39
4	1	17.60	33.10	18.70	16.10
	2	22.40	36.10	15.00	19.47
	3	19.40	32.70	17.20	11.00
	4	18.10	35.10	21.90	8.40
	5	18.10	27.50	16.20	10.10
	6	15.20	40.00	24.50	16.30
	M	17.98	34.72	20.37	12.82
	SD	1.56	4.77	3.48	3.40

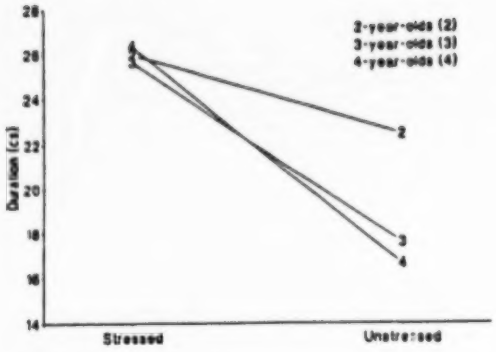

Figure 3. Two-way age by stress level interaction for duration measure.

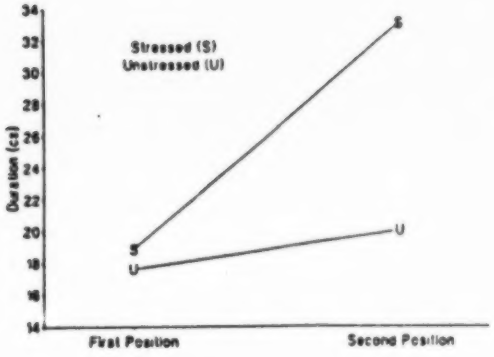

Figure 4. Two-way stress level by syllable position interaction for duration measure.

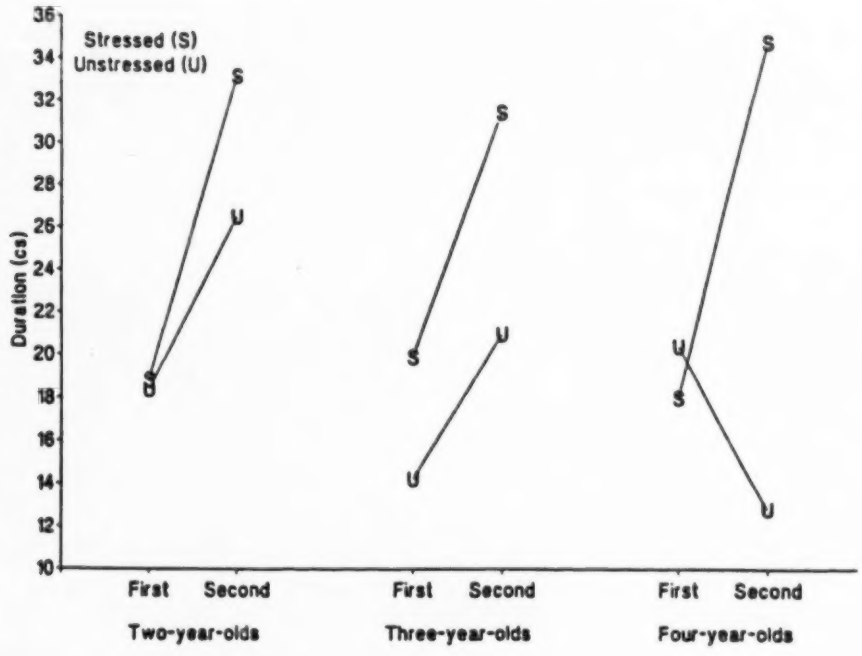

Figure 5. Three-way age by stress level by syllable position interaction for duration measure.

displays this interaction. For the two-year-olds, second syllables are still longer than first syllables, but stressed syllables are also longer than unstressed syllables, regardless of position. However, the difference between stressed and unstressed syllable duration appears greater in second position. For the four-year-olds, second syllables are longer than first syllables only if they are stressed. Second syllables are shorter when they are unstressed.

It is interesting to look at the absolute duration values for the 'CVCV targets. Across the age groups, the duration of the first vowel remains relatively constant, around 18 to 20 centiseconds. However, the absolute duration of the second vowel declines with increased age, from 26 cs at two years, to 21 cs at three years, and finally to 13 cs at four years, indicating that the children are learning to reduce the length of unstressed syllables.

Discussion

The results of the present study suggest that all three of the acoustic features measured (intensity, fundamental frequency, and duration) are rather poorly controlled at two years of age. At three years of age, both intensity and fundamental frequency are used consistently to mark the stressed syllable, regardless of its position in the word. However, it is not until four years of age that children seem to have control over duration as a feature for marking word stress.

The present data also argue for a neutral start hypothesis for early stress production. The two year olds produced changes in intensity and fundamental frequency on individual tokens, but not consistently any direction. Instances of incorrect stress placement were seen not only in the use of first syllable stress for second syllable stressed targets, as would be predicted by the trochaic hypothesis, but also in the use of second syllable stress for first syllable stressed targets, in direct opposition to the trochaic hypothesis.

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